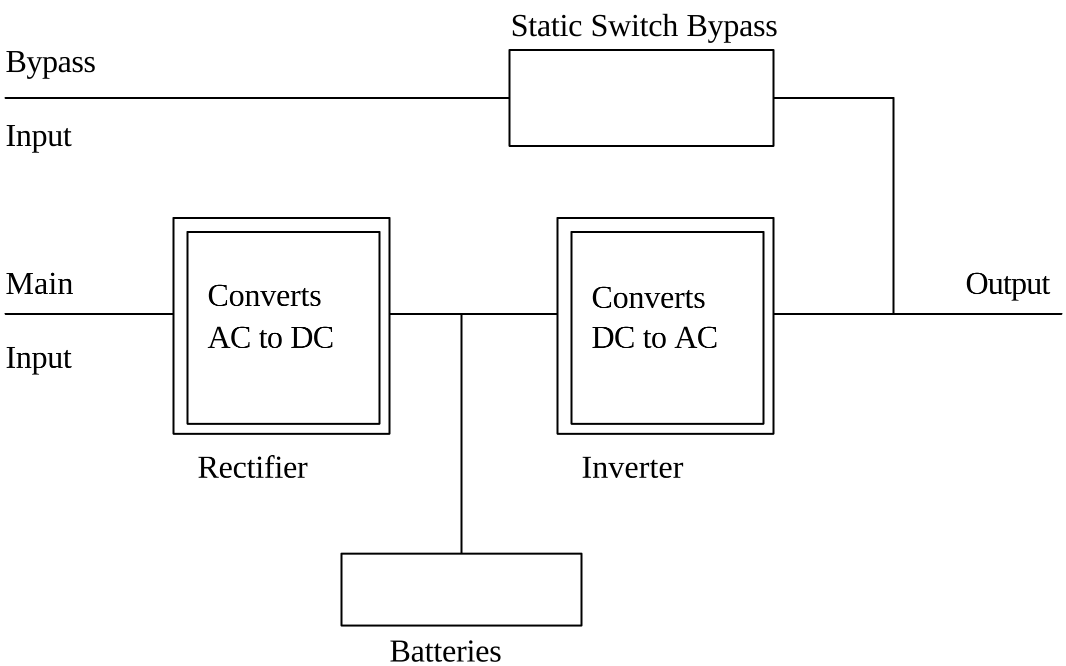
The Turtle, The Hare and UPS Performance

(This Time the Rabbit Wins!)

By Thomas E. Wilson, P.E.

Wilson Engineered Systems, Inc.
11497 Columbia Park Drive West, Suite #2
Jacksonville, FL 32258

UPS systems are technical products. Various designs which externally seem similar are internally very different. These differences genuinely cause significant performance differences in quality of performance and longevity of components. Below is a simplified diagram of the building blocks of a UPS module.



The selection of components in the rectifier and the inverter affects input characteristics, output characteristics as well as battery and bypass use. The goal is to satisfy output demands of the supported critical load while minimizing use of batteries and bypass and to minimize problems created by the input. Stating that is the simple part.

Loads today have high harmonics and in some applications have high step loading changes. Step loads are created by motor loads, loads which turn on and off, loads where

PDUs can be energized while on UPS and when parallel or isolated redundant designs are used and anytime loads switch to and from bypass circuits.

When the load changes, the inverter must supply the current or the bypass will have to assist or take over, neither desirable. When the inverter needs current, it must come from either the rectifier (desirable) or battery (not desirable). Thus the inverter must be fast enough and the rectifier must match it. Otherwise bypass or batteries need to be used to assist.

Looking at UPS designs, there are various vintages of product design in place today some of which are surprisingly old (but cheap!).

Rectifiers

SCR based 6 pulse phase controlled rectifiers. These are the lowest cost, have severe waveform notching, high distortion (30%) at full load, even higher at light load and are slow, 6 decisions per cycle. Filters are required to reduce distortion.

SCR based 12 pulse pulse phase controlled rectifiers. These are low cost, have severe waveform notching, lower but still high distortion (12%) at full load, higher at light load and are slow, 12 decisions per cycle. Filters are required to reduce distortion.

IGBT rectifiers. These are highest cost, no waveform notching, have low distortion (3% at full load, 5% at 50% load), 30 to 100 decisions per cycle. No filters required.

Diode Bridge/IGBT rectifers. These are hybrid design with high cost, no waveform notching, low distortion (6% at full load, 9% at 50% load) (small filter is generally included). Diode bridge portion just operates without decisions required and IGBT portion operates at 30 to 100 decisions per cycle.

Inverters

6 step SCR similar to 6 pulse rectifier, low cost, largest filter required

12 step SCR similar to 12 pulse rectifier, low cost, still filtered

IGBT similar to, often identical to, IGBT rectifier, no filter required.

The Turtle and Hare

A 6 pulse/step device is a turtle in modern power component technology, 12 pulse/step devices are two turtles, IGBT devices are packs of rabbits.

In the early 1980’s most UPS were 12 pulse rectifiers and 12 step inverters. While turtles each, they were matched turtles. However during that period loads were linear, turtle like loads. In the late 1980's some UPS manufacturers dropped a turtle on the rectifier going to 6 pulse rectifiers and batteries began to see more hidden use.

Next to come were 6 pulse rectifiers and transistorized inverters in the late 1980s. Surprisingly three of the four major UPS manufactures still use this arrangement in the year 2003. This is truly a turtle and rabbit scenario and has caused some of the battery reliability issues in the industry. The turtle rectifier cannot keep up with the rabbit inverter so bypass or battery assist, mostly the battery. This over use of the battery will cause shorter battery life. We have analyzed one site with two UPS systems with turtle to rabbit designs actually needed the battery to help the rectifier when utility voltage sagged only 5% percent, despite the manufacturer's published specifications which stated no battery use till a 15% utility sag.

Next in the mid 1990's the IGBT rectifier technology came into play. This is a rabbit rectifier, rabbit inverter design. Incorporation of the technology allows high step loading and harmonic loading without using the battery except for true outages. The diode bridge/IGBT rectifier came in the late 1990's and is a similar concept for purposes of this article. The distortion numbers are marginally higher on this hybrid.

Generally of the four major players in the UPS industry, the Japanese product incorporates IGBT technology in the rectifier and inverter. The "US companies", actually Mexican and French units, generally utilize IGBT inverters and mostly 6 pulse rectifers, some 12 pulse.

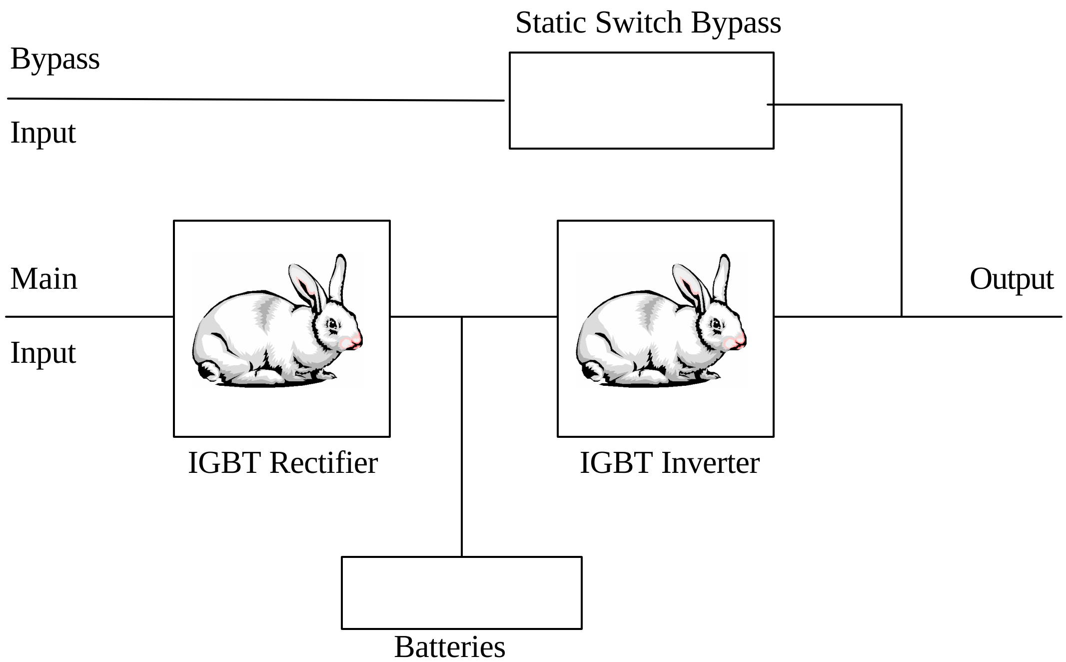
The figures on the following pages depict the situation in a simplified but very representative format. Many thanks to Mark Baldwin of Baldwin Technologies for bringing the turtle and rabbit analogy to describe this topic. Having personally described the situation in terms of fast and slow components for several years his analogy certainly provides for a much more easily understood vision of the situation on a somewhat dry but important topic.

Keep in mind that when literature speaks of being "transistorized UPS", that is an incomplete description. Having one transistor may make a UPS "transistorized" but doesn't mean the benefit of a truly all transistorized UPS has been realized. Similarly putting in transistors but controlling them like SCRs does not provide the benefit of having used transistors. For high performance insist on,

- IGBT Rectifier
- IGBT Inverter
- IGBT switching speeds above 30 per cycle or 2 kHz and above.

(Note on switching speed. Highest is not always best because of switching losses. Highest provides better waveforms, but switching losses reduce efficiency. Therefore best switching speed is a compromise of speed and efficiency.)

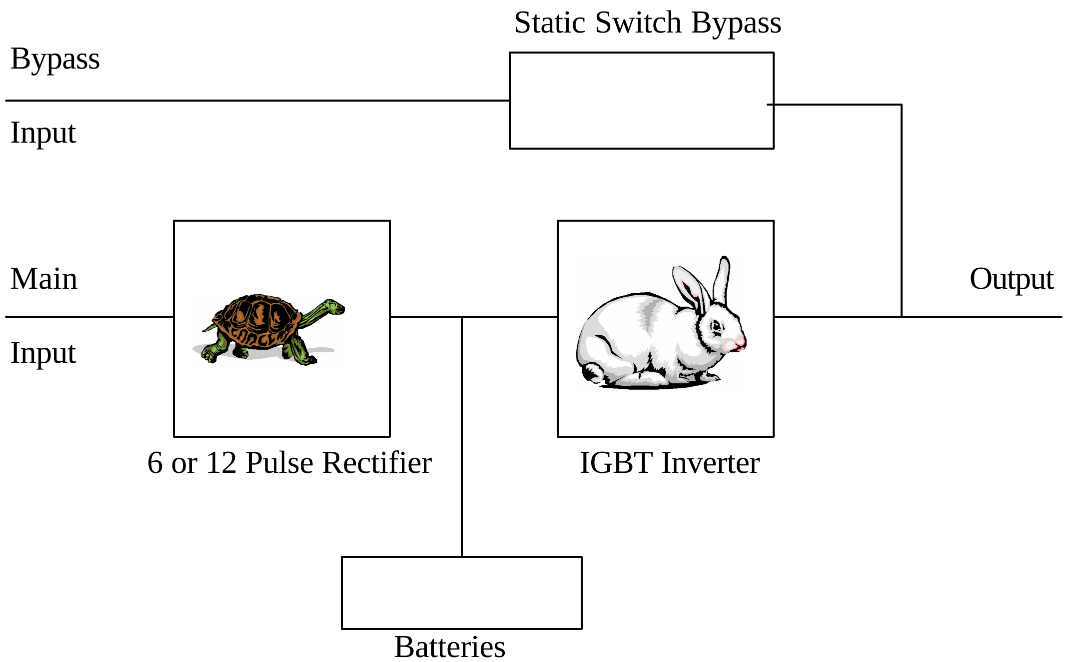
IGBT Rectifier with IGBT Inverter



The IGBT rectifiers with IGBT inverters have the following benefits,

- Rectifier speed matches with inverter needs
- Handles high step loading without using battery or bypass
- Maximizes battery life as battery is not required to support inverter for harmonic and step load needs
- Eliminates transfers to bypass for step loading
- Rectifier puts out low ripple which maximizes battery life
- Well suited for high performance in parallel UPS design
- Only design that should be selected for isolated redundant designs

6 or 12 Pulse Rectifier with IGBT Inverter



The 6 or 12 pulse rectifiers with IGBT or transistorized inverters have the following concerns,

- Rectifier speed cannot keep up with (i.e. react to) inverter needs
- Cannot handle high step loading without using battery or bypass
- Reduces battery life as battery is routinely called upon for harmonic and step load needs
- Rectifier puts out higher ripple which causes battery to act as a ripple filter, again reducing battery life
- Not well suited for high performance in parallel UPS design
- Should not be used for isolated redundant designs